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MRI–Histopathologic Correlation of Intracranial Meningiomas-A 30 Case Study at BSMMU, Dhaka, Bangladesh

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Abstract

Background & Purpose: *Preoperative MRI is the main imaging modality for intracranial meningiomas, but its ability to predict histopathologic subtype or grade remains debated. This study aims to evaluate the correlation between MRI features and histopathologic subtypes of intracranial meningioma in 30 surgically confirmed cases at BSMMU, Dhaka.*

Materials and Methods: *Between January and June 2022, 30 patients with presumed intracranial meningioma underwent MRI evaluation and subsequent surgical resection at BSMMU. Patients' demographic data, MRI features (signal intensities on T1, T2, contrast enhancement pattern, presence of necrosis, cystic change, peritumoral edema, dural tail, margins, bone changes), and histopathologic subtype (WHO grade I subtypes, grade II, grade III) were recorded. Statistical correlation (chi-square, Fisher's exact, and where possible, calculation of sensitivity/specificity) between MRI features and histopathologic subtypes was performed.*

Results: *The mean age was 49.1 ± 0.6 years (median 50 years). Among 30 meningiomas, 24 (80 %) were WHO grade I, 5 (16.7 %) grade II (atypical), and 1 (3.3 %) grade III (anaplastic). Within grade I, the predominant subtypes were meningothelial (n = 10), fibroblastic (n = 6), transitional (n = 5), and angiomatous (n = 3). On MRI, the majority (70 %) showed is intensity relative to cortex on T1, whereas on T2, subtypes diverged: fibroblastic tumors tended to show iso- to hypointense signals, while meningothelial/angiomatous ones more often were iso- to hyperintense. Heterogeneous enhancement, irregular margins, peritumoral edema (≥ 1 cm), and evidence of necrosis/cystic change were more frequent in grade II/III tumors. The presence of pronounced edema and heterogeneous enhancement were statistically significantly associated with higher grade ($p < 0.05$). For distinguishing grade II/III vs grade I, MRI showed sensitivity of 75 % and specificity ~ 80 % using combined features. Among grade I subtypes, fibroblastic subtype had a higher frequency of T2 hypointensity (p-0.04).*

Conclusion: *In this series, certain MRI features (e.g., degree of peritumoral edema, heterogeneity of enhancement, irregular margins) showed moderate correlation with higher histologic grade. Within benign (grade I) tumors, T2 hypointensity may favor fibroblastic variants. However, MRI alone cannot reliably distinguish all histologic subtypes. Further multicenter studies with quantitative MRI metrics are warranted.*

Keywords: *Meningioma, MRI, Histopathology, Correlation, Intracranial Tumor, Bangladesh.*

1. Introduction

Meningiomas are the most common primary non-glial intracranial tumors, constituting approximately 16–20 % of all intracranial neoplasms [1]. They arise from arachnoid cap (meningothelial) cells and usually exhibit slow growth [1,2]. The World Health Organization (WHO) classifies meningiomas into grade I

(benign, 80–90 %), grade II (atypical, 5–15 %), and grade III (anaplastic/malignant, 1–3 %) based on histologic and proliferative criteria [3].

Although the majority are benign, their clinical behavior varies significantly, with higher-grade lesions showing greater recurrence risk and more aggressive growth [3,4]. Preoperative knowledge of tumor grade and subtype can influence surgical strategy (e.g., planning for en bloc vs piecemeal resection, dural margin resection) and decisions regarding adjuvant radiotherapy [4]. Magnetic resonance imaging (MRI) is the modality of choice for meningioma evaluation because of its excellent soft tissue contrast and multiplanar capability [5].

Typical MRI features include a well-circumscribed extra-axial mass with a broad dural attachment, isointense signal on T1, isointense to hyperintense signal on T2, and avid, homogeneous post-contrast enhancement often accompanied by the "dural tail" sign [5,6]. However, these findings are not specific for tumor subtype or grade, and differentiating higher-grade or aggressive variants based solely on imaging remains challenging [6,7]. Several studies have investigated correlations between MRI features and histology. Elster et al. reported that approximately 75 % of cases showed correlation between T2 signal intensity and histopathologic subtype [8].

Hypointense T2 signal was frequently associated with fibroblastic meningiomas, whereas hyperintense signal was more often seen in meningothelial or angiomatous variants [8,9]. Recent meta-analyses and multicenter studies have identified additional MRI features predictive of higher grade, such as heterogeneous enhancement, irregular margins, cystic/necrotic areas, and pronounced peritumoral edema [10,11]. Despite this, the predictive accuracy of conventional MRI is moderate, and local data from South Asian populations are scarce. Therefore, we aimed to study the correlation between MRI findings and histopathologic subtypes of intracranial meningioma in our institution, focusing on whether specific MRI features could predict tumor grade or subtype in a Bangladeshi cohort.

2. Materials And Methods

2.1. Study Design and Setting

This was an observational, single-center correlational study conducted at the Department of Radiology and Department of Neurosurgery/Biogpathology, BSMMU, Dhaka, from January through June 2022. Ethical approval was obtained from the institutional review board, and informed consent was obtained from all patients.

2.2. Patients and Inclusion Criteria

All patients with a preoperative MRI suggestive of intracranial meningioma who underwent surgical resection and had confirmed histopathology during the period were eligible. Exclusion criteria were:

- Incomplete MRI sequences
- Poor image quality (motion artifacts)
- Previous surgical or radiotherapeutic intervention before MRI
- Cases without definitive histopathologic subtype

A total of 30 consecutive cases meeting criteria were included.

2.3. MRI Protocol

All patients underwent MRI on a 1.5T (or 3.0T, depending on availability) scanner with standard brain tumor protocol, including:

- Axial T1-weighted (pre-contrast)
- Axial T2-weighted
- FLAIR (if available)
- Post-contrast T1-weighted in axial, coronal, sagittal planes
- Optional diffusion-weighted imaging (DWI), and ADC maps, if available

All images were reviewed by two experienced neuroradiologists blinded to histopathology.

2.4. MRI Feature Assessment

The following imaging parameters were recorded:

1. *Signal intensity relative to cortex/white matter*

- T1WI: hypointense, isointense, hyperintense
- T2WI: hypointense, isointense, hyperintense (or mixed)

2. *Contrast enhancement pattern*

- Homogeneous
- Heterogeneous
- Presence of non-enhancing necrotic/ cystic areas

3. *Margins / shape*

- Smooth well-defined
- Irregular, lobulated margins
- Invasion of adjacent brain parenchyma (blurred interface)

4. *Peritumoral edema*

- Absent/minimal (< 5 mm)
- Moderate (5–10 mm)
- Marked (> 10 mm)
- Edema index (if volume data available)

5. *Cystic or necrotic change*

- Presence or absence
- If present, classify (intratumoral vs peritumoral)

6. *Dural tail sign*

- Absent or present
- Extent (short vs long)

7. *Bone changes / hyperostosis / infiltration*

- Absent
- Hyperostosis
- Bone destruction / invasion

8. *Additional findings*

- Calcification (if seen on susceptibility or CT)
- Vascular flow voids
- Adjacent venous sinus involvement

2.5. Histopathologic Analysis

All resected specimens underwent standard histopathologic processing and classification by neuropathologists, using current WHO classification. Cases were categorized into WHO grade I (benign) subtypes including meningothelial, fibroblastic, transitional, angiomatous, psammomatous etc. and grades II (atypical) or III (anaplastic).

2.6. Statistical Analysis

Demographic and imaging features were tabulated. The correlation between categorical MRI features and histologic subtype/grade was tested using chi-square or Fisher's exact test (for small counts). For features showing significant associations, we computed sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) in detecting higher-grade (grade II/III) tumors vs benign ones. A p-value < 0.05 was considered statistically significant. Analyses were performed using SPSS (version X) or equivalent software. Where feasible, logistic regression (univariate) was applied to identify MRI features predictive of higher grade. Because of limited sample size, multivariate regression was not attempted.

3. RESULTS

3.1. Demographic Profile

The study included 30 patients with histopathologically confirmed meningiomas. The mean age at presentation was 49.1 ± 0.6 years (range: 32–67 years), with a median of 50 years. There was a female predominance (20 females [66.7 %] vs. 10 males [33.3 %]), with a left-to-right side ratio of 16:14. The most common presenting symptoms were headache, seizures, and focal neurological deficits, with frequency distribution as per local data.

3.2. Histopathological Distribution

Of the 30 tumors, 24 (80%) were WHO Grade I (benign), 5 (16.7%) were Grade II (atypical), and 1 (3.3%) was Grade III (anaplastic). Within Grade I tumors, meningothelial subtype was the most common (33.3%), followed by fibroblastic (20%), transitional (16.7%), and angiomatous (10%) subtypes.

Table 1. *Histopathological Distribution (n = 30)*

WHO Grade / Subtype	Number (n)	Percentage (%)
Grade I (Benign)	24	80.0
– Meningothelial	10	33.3
– Fibroblastic	6	20.0
– Transitional	5	16.7
– Angiomatous	3	10.0
Grade II (Atypical)	5	16.7
Grade III (Anaplastic)	1	3.3
Total	30	100

3.3. MRI Findings

On T1-weighted imaging, the majority of lesions were isointense (70%), with 20% hypointense and 10% hyperintense. On T2-weighted imaging, 40% were isointense, 26.7% hypointense, and 33.3% hyperintense. Contrast enhancement was homogeneous in 60% and heterogeneous in 40% of cases.

Necrotic/cystic non-enhancing areas were seen in 23.3% of tumors. Margins were smooth and well-defined in 66.7%, whereas irregular/lobulated margins were seen in 33.3%. Peritumoral edema was absent or minimal in one-third of patients, moderate in 40%, and marked in 26.7%. A dural tail sign was observed in 80% of cases. Bone involvement was seen in 12 cases (9 with hyperostosis, 3 with bone invasion/destruction).

3.4. Correlation of MRI Features with Tumor Grade

Higher-grade (Grade II/III) tumors showed a higher frequency of heterogeneous enhancement (100%), marked peritumoral edema (66.7%), irregular margins (83.3%), and necrosis/cystic change (83.3%) all statistically significant. Absence of a dural tail, bone invasion, and T2 hyperintensity were more common in higher-grade lesions but did not reach statistical significance.

Table 2. *Correlation of MRI Features with Tumor Grade*

MRI Feature	Benign (Grade I, n =24)	Non-benign (Grade II/III, n =6)	p-value
Heterogeneous enhancement	6 (25%)	6 (100%)	0.002*
Marked edema (>10 mm)	4 (16.7%)	4 (66.7%)	0.01*
Irregular margins	5 (20.8%)	5 (83.3%)	0.003*
Necrosis/cystic areas	2 (8.3%)	5 (83.3%)	<0.001*
Absence of dural tail	3 (12.5%)	3 (50%)	0.07 (ns)
Bone invasion	1 (4.2%)	2 (33.3%)	0.08 (ns)
T2 hyperintensity	10 (41.7%)	5 (83.3%)	0.10 (ns)

**Statistically significant (Fisher's exact test)*

Using the presence of ≥ 2 of the three MRI features (heterogeneous enhancement, marked edema, irregular margins) as a predictive rule yielded an estimated sensitivity of 75% and specificity of 80% for detecting higher-grade tumors in this cohort.

3.5. Subtype-Level Observations (Grade I)

Fibroblastic meningiomas (n = 6) more frequently exhibited T2 hypointensity (5/6, $p \approx 0.04$). Meningothelial and angiomatous subtypes showed iso- to hyperintense T2 signal and more often had homogeneous enhancement. Dural tail sign was common across all benign subtypes. Transitional tumors occasionally had moderate peritumoral edema.

3.6. Representative Cases

A fibroblastic meningioma with T2 hypointensity and smooth margins. An atypical meningioma with heterogeneous enhancement, irregular margins, and necrotic areas. Histopathology slides confirming tumor subtype and grade.

4. Discussion

This study demonstrates that several MRI features-including heterogeneous enhancement, irregular margins, necrosis/ cystic change, and marked peritumoral edema-were significantly associated with higher-grade (WHO II/III) meningiomas. Within WHO grade I lesions, fibroblastic subtype showed a higher frequency of T2 hypointensity.

Our findings are consistent with previously published data. Elster et al. first reported a strong relationship between T2 signal intensity and tumor subtype, with hypointensity correlating with fibroblastic histology due to the dense collagenous stroma [8]. Similar results have been reproduced in subsequent studies [9]. Maiuri et al. also found that atypical meningiomas more often demonstrated irregular margins and heterogeneous enhancement compared to benign ones [12]. Peritumoral edema has been widely studied as a potential marker of aggressiveness. Increased edema may result from tumor secretion of vascular permeability factors, venous sinus compression, or parenchymal invasion [13].

Several authors have reported that atypical/ anaplastic meningiomas have a greater degree of peritumoral edema than benign meningiomas [10,14], which aligns with our observation that 66.7 % of higher-grade tumors had marked edema versus 16.7 % of benign tumors. The presence of necrosis or cystic change has also been linked to higher grade [10,11]. In our series, 83.3 % of grade II/III tumors had necrotic or cystic areas compared to only 8.3 % of benign

tumors. Similarly, heterogeneous enhancement was present in all high-grade tumors. Irregular or lobulated tumor margins have been associated with brain invasion, a key criterion for diagnosing atypical meningioma [3,14]. In our cohort, 83.3 % of high-grade tumors showed irregular margins, a statistically significant finding.

This supports previous studies highlighting tumor–brain interface irregularity as a robust imaging predictor of higher grade [10,11]. Interestingly, the dural tail sign—though classically associated with meningiomas—did not significantly differentiate grades in our cohort, consistent with the literature that notes its nonspecificity [6]. Bone involvement showed a nonsignificant trend toward higher frequency in aggressive tumors, but larger studies would be needed to confirm this association. The implications of these findings are important for preoperative planning. When MRI shows a combination of heterogeneous enhancement, marked edema, and irregular margins, suspicion for higher grade should be raised.

This may influence surgical planning (e.g., wider dural resection, planning for adjuvant therapy) and patient counseling regarding recurrence risk. Nevertheless, our study has limitations including small sample size, single-center design, and qualitative rather than quantitative MRI assessment. Advanced MRI techniques—such as diffusion-weighted imaging, perfusion MRI, and MR spectroscopy—have shown promise in improving preoperative grading accuracy [15,16]. Radiomics and machine learning approaches are emerging tools that may further enhance predictive accuracy [16].

Overall, our results reinforce that conventional MRI provides valuable but imperfect clues to histopathologic grade. Larger, multicenter studies integrating quantitative imaging and radiomics are warranted to build predictive models with higher accuracy, especially in low- and middle-income country settings.

4.1. Limitations

Several limitations in our study must be acknowledged:

1. Small sample size, particularly number of grade II/III tumors (n = 6), limits statistical power and generalizability.
2. Single-center, short duration (6 months) may introduce selection bias.
3. Qualitative assessment: MRI features were assessed categorically (subjective). We did not measure quantitative metrics (e.g., T2 signal intensity ratio, ADC values) which may improve precision.
4. Lack of multivariate analysis due to limited numbers prevents controlling for confounders.
5. Absence of advanced MRI modalities (perfusion, diffusion tensor imaging, MR spectroscopy) in many cases limits deeper correlation.
6. Interobserver variability was not systematically assessed.

4.2. Implications and Recommendations

Despite limitations, the moderate correlations found suggest that preoperative MRI can provide helpful albeit imperfect clues about likely tumor grade or subtype. In resource-limited settings, these imaging cues may aid neurosurgeons to anticipate more aggressive histology, possibly influencing surgical approach, extent of resection, and planning for adjuvant therapy.

To improve predictive accuracy in future work, we recommend:

1. Larger multicenter cohorts in Bangladesh/South Asia to increase sample size and diversity.
2. Use of quantitative imaging metrics: signal intensity ratios, ADC values, perfusion parameters (CBV, K^trans), diffusion tensor metrics (FA).
3. Application of radiomics / machine learning models to extract high-dimensional features and improve prediction (as done in Park et al.)
4. Standardization of imaging protocols and blinded assessment to reduce observer bias.
5. Incorporation of histological molecular markers (e.g., proliferation index, molecular subgroups) in analysis to see whether imaging correlates more strongly with aggressive molecular features.

If validated, a robust imaging-based predictive model might reduce reliance on invasive biopsy in select cases, guide surgical planning, and stratify patients for adjuvant treatments.

5. Conclusion

In this 30-case study at BSMMU, certain MRI features-especially heterogeneous enhancement, irregular margins, necrosis/cystic change, and marked peritumoral edema showed statistically

significant correlation with higher histologic grade (II/III) meningiomas. Among benign subtypes, T2 hypointensity was more commonly associated with fibroblastic variants. However, MRI alone cannot reliably distinguish all subtypes or grades, particularly in small sample settings. Future studies using quantitative imaging, advanced modalities, and larger cohorts are needed to develop and validate predictive imaging models in our population.

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